

# Cortex™-A9 NEON™ Media Processing Engine

Revision: r3p0

## Technical Reference Manual

**ARM®**

# Cortex-A9 NEON Media Processing Engine

## Technical Reference Manual

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### Release Information

The following changes have been made to this book.

Change history			
Date	Issue	Confidentiality	Change
04 April 2008	A	Non-Confidential	First release for r0p0
10 July 2008	B	Non-Confidential Restricted Access	Second release for r0p0
12 Dec 2008	C	Non-Confidential Restricted Access	First release for r1p0
24 September 2009	D	Non-Confidential Restricted Access	First release for r2p0
27 November 2009	E	Non-Confidential Unrestricted Access	Second release for r2p0
27 April 2010	F	Non-Confidential Unrestricted Access	First release for r2p2
21 July 2011	G2	Non-Confidential	First release for r3p0

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The information in this document is final, that is for a developed product.

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# Preface

This preface introduces the *Cortex-A9 NEON™ Media Processing Engine (MPE) Technical Reference Manual*. It contains the following sections:

- *About this book on page v*
- *Feedback on page vii.*

## About this book

This book is for the Cortex-A9 NEON MPE.

## Product revision status

The *rn* identifier indicates the revision status of the product described in this book, where:

- rn** Identifies the major revision of the product.
- pn** Identifies the minor revision or modification status of the product.

## Intended audience

This book is written for system designers, system integrators, and verification engineers who are designing a *System-on-Chip* (SoC) device that uses the Cortex-A9 NEON MPE. The book describes the external functionality of the Cortex-A9 MPE.

## Using this book

This book is organized into the following chapters:

### Chapter 1 *Introduction*

Read this for a high-level view of the Cortex-A9 NEON MPE and a description of its features.

### Chapter 2 *Programmers Model*

Read this for a description of the Cortex-A9 NEON MPE system registers.

### Chapter 3 *Instruction Timing*

Read this for a description of the cycle timings of instructions on the Cortex-A9 NEON MPE.

### Appendix A *Revisions*

Read this for a description of the technical changes between released issues of this book.

## Conventions

Conventions that this book can use are described in:

- *Typographical*

### Typographical

The typographical conventions are:

- italic* Introduces special terminology, denotes cross-references, and citations.
- bold** Highlights interface elements, such as menu names. Denotes signal names. Also used for terms in descriptive lists, where appropriate.
- monospace Denotes text that you can enter at the keyboard, such as commands, file and program names, and source code.
- monospace Denotes a permitted abbreviation for a command or option. You can enter the underlined text instead of the full command or option name.
- monospace italic* Denotes arguments to monospace text where the argument is to be replaced by a specific value.

<b>monospace bold</b>	Denotes language keywords when used outside example code.
<b>&lt; and &gt;</b>	Enclose replaceable terms for assembler syntax where they appear in code or code fragments. For example: MRC p15, 0 <Rd>, <CRn>, <CRm>, <Opcode_2>

## Additional reading

This section lists publications by ARM and by third parties.

See Infocenter, <http://infocenter.arm.com>, for access to ARM documentation.

See the glossary, <http://infocenter.arm.com/help/topic/com.arm.doc.aeg0014-/index.html>, for a list of terms and acronyms specific to ARM.

## ARM publications

This book contains information that is specific to this product. See the following documents for other relevant information:

- *Cortex-A9 Technical Reference Manual* (ARM DDI 0388)
- *Cortex-A9 MPCore Technical Reference Manual* (ARM DDI 0407)
- *Cortex-A9 Floating-Point Unit Technical Reference Manual* (ARM DDI 0408)
- *Cortex-A9 MBIST Controller Technical Reference Manual* (ARM DDI 0414)
- *Cortex-A9 Configuration and Sign-Off Guide* (ARM DII 0146)
- *CoreSight™ PTM™-A9 Technical Reference Manual* (ARM DDI 0401)
- *CoreSight PTM-A9 Configuration and Sign-Off Guide* (ARM DII 0161)
- *CoreSight PTM-A9 Integration Manual* (ARM DII 0162)
- *CoreSight Program Flow Trace Architecture Specification* (ARM IHI 0035)
- *AMBA® Level 2 Cache Controller (L2C-310) Technical Reference Manual* (ARM DDI 0246)
- *L220 Cache Controller Technical Reference Manual* (ARM DDI 0329)
- *AMBA AXI Protocol Specification* (ARM IHI 0022)
- *AMBA Specification* (ARM IHI 0011)
- *ARM Architecture Reference Manual, ARMv7-A and ARMv7-R edition* (ARM DDI 0406)
- *RealView™ Compilation Tools Developer Guide* (ARM DUI 0203)
- *RealView ICE and RealView Trace User Guide* (ARM DUI 0155)
- *Intelligent Energy Controller Technical Overview* (ARM DTO 0005).

## Other publications

This section lists relevant documents published by third parties:

- *ANSI/IEEE Std 754-1985, IEEE Standard for Binary Floating-Point Arithmetic.*

## Feedback

ARM welcomes feedback on this product and its documentation.

### Feedback on this product

If you have any comments or suggestions about this product, contact your supplier and give:

- The product name.
- The product revision or version.
- An explanation with as much information as you can provide. Include symptoms and diagnostic procedures if appropriate.

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- the title
- the number, ARM DDI 0409G
- the page numbers to which your comments apply
- a concise explanation of your comments.

ARM also welcomes general suggestions for additions and improvements.

# Chapter 1

## Introduction

This chapter introduces the Cortex-A9 implementation of the ARM Advanced SIMD media processing architecture. It contains the following sections:

- *About the Cortex-A9 NEON MPE on page 1-2*
- *Applications on page 1-4*
- *Product revisions on page 1-5.*



## 1.1 About the Cortex-A9 NEON MPE

The Cortex-A9 NEON MPE extends the Cortex-A9 functionality to provide support for the ARM v7 *Advanced SIMD* and *Vector Floating-Point v3* (VFPv3) instruction sets. The Cortex-A9 NEON MPE supports all addressing modes and data-processing operations described in the *ARM Architecture Reference Manual*.

The Cortex-A9 NEON MPE features are:

- SIMD and scalar single-precision floating-point computation
- scalar double-precision floating-point computation
- SIMD and scalar half-precision floating-point conversion
- 8, 16, 32, and 64-bit signed and unsigned integer SIMD computation
- 8 or 16-bit polynomial computation for single-bit coefficients
- structured data load capabilities
- dual issue with Cortex-A9 processor ARM or Thumb instructions
- independent pipelines for VFPv3 and Advanced SIMD instructions
- large, shared register file, addressable as:
  - thirty-two 32-bit S (single) registers
  - thirty-two 64-bit D (double) registers
  - sixteen 128-bit Q (quad) registers.

See the *ARM Architecture Reference Manual* for details of the information that the MPE can hold in the different register formats.

The Cortex-A9 NEON MPE provides high-performance SIMD vector operations for:

- unsigned and signed integers
- single bit coefficient polynomials
- single-precision floating-point values.

The operations include:

- addition and subtraction
- multiplication with optional accumulation
- maximum or minimum value driven lane selection operations
- inverse square-root approximation
- comprehensive data-structure load instructions, including register-bank-resident table lookup.

See the *ARM Architecture Reference Manual* for details of the Advanced SIMD instructions.

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**Note**

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The Advanced SIMD architecture extension, its associated implementations, and supporting software, are commonly referred to as NEON™ technology.

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### 1.1.1 VFPv3 architecture hardware support

The Cortex-A9 NEON MPE hardware supports single and double-precision add, subtract, multiply, divide, multiply and accumulate, and square root operations as described in the ARM VFPv3 architecture. It provides conversions between 16-bit, 32-bit and 64-bit floating-point formats and ARM integer word formats, with special operations to perform conversions in round-towards-zero mode for high-level language support.

All instructions are available in both the ARM and Thumb instruction sets supported by the Cortex-A9 processor family.

The Cortex-A9 NEON MPE provides an optimized solution in performance, power, and area for embedded and media intensive applications.

ARMv7 deprecates the use of VFP vector mode. The Cortex-A9 NEON MPE hardware does not support VFP vector operations. In this manual, the term vector refers to Advanced SIMD integer, polynomial and single-precision vector operations. The Cortex-A9 NEON MPE provides high speed VFP operation without support code. However, if an application requires VFP vector operation, then it must use support code. See the *ARM Architecture Reference Manual* for information on VFP vector operation support.

———— **Note** —————

This manual gives information specific to the Cortex-A9 NEON MPE implementation of the ARM Advanced SIMD and VFPv3 extensions. See the *ARM Architecture Reference Manual* for full instruction set and usage details.

---

## 1.2 Applications

The Cortex-A9 NEON MPE provides mixed-data type SIMD and high-performance scalar floating-point computation suitable for a wide spectrum of applications such as:

- personal digital assistants and smartphones for graphics, voice compression and decompression, user interfaces, Java interpretation, and *Just In Time (JIT)* compilation
- games machines for intensive three-dimensional graphics, digital audio and in-game physics effects such as gravity
- printers and *MultiFunction Peripheral (MFP)* controllers for high-definition color rendering
- set-top boxes for high-end digital audio and digital video, and interactive three-dimensional user interfaces
- automotive applications for engine management, power train computation, and in-car entertainment and navigation.

## 1.3 Product revisions

This section describes the differences in functionality between product revisions:

**r0p0 - r1p0** There are no functionality changes although you must use the Cortex-A9 revision r1p0 design with revision r1p0 NEON MPE.

**r1p0 - r2p0** There are no functionality changes although you must use the Cortex-A9 revision r2p0 design with this revision r2p0 NEON MPE.

**r2p0 - r2p1** There are no functionality changes although you must use the Cortex-A9 revision r2p1 design with this revision r2p1 NEON MPE.

**r2p1- r2p2** There are no functionality changes.

**r2p2- r3p0** There are no functionality changes.

# Chapter 2

## Programmers Model

This chapter describes the Cortex-A9 NEON MPE programmers model. It contains the following sections:

- *About this programmers model on page 2-2*
- *New Advanced SIMD and VFP features on page 2-4*
- *IEEE754 standard compliance on page 2-5*
- *Supported formats on page 2-6*
- *Advanced SIMD and VFP register access on page 2-7*
- *Register summary on page 2-11*
- *Register descriptions on page 2-12.*

## 2.1 About this programmers model

This section introduces the VFPv3 and Advanced SIMD implementation provided by the Cortex-A9 NEON MPE. In addition it provides information on initializing the Cortex-A9 NEON MPE ready for application code execution. These are described in:

- [Advanced SIMD and VFP feature identification registers](#)
- [Enabling Advanced SIMD and floating-point support](#).

In addition to features provided in previous combined Advanced SIMD and VFP implementations, the Cortex-A9 NEON MPE provides:

- half-precision, 16-bit, floating-point value conversion
- support for emulation of VFPv3-D32 and VFPv3-D16.

See the *ARM Architecture Reference Manual* for more information.

### 2.1.1 Advanced SIMD and VFP feature identification registers

The Cortex-A9 NEON MPE implements the ARMv7 Advanced SIMD and VFP extensions.

Software can identify these extensions and the features they provide, using the feature identification registers. The extensions are in the coprocessor space for coprocessors CP10 and CP11. You can access the registers using the VMRS and VMSR instructions, for example:

```
VMRS <Rd>, FPSID ; Read Floating-Point System ID Register
VMRS <Rd>, MVFR1 ; Read Media and VFP Feature Register 1
VMSR FPSCR, <Rt> ; Write Floating-Point System Control Register
```

See [Advanced SIMD and VFP register access on page 2-7](#) for a description of the registers.

In addition there are coprocessor access control registers. See [Non-secure Access Control Register on page 2-8](#) and [Coprocessor Access Control Register on page 2-7](#).

### 2.1.2 Enabling Advanced SIMD and floating-point support

From reset, both the Advanced SIMD and VFP extensions are disabled. Any attempt to execute either a NEON or VFP instruction results in an Undefined Instruction exception being taken. To enable software to access Advanced SIMD and VFP features ensure that:

- Access to CP10 and CP11 is enabled for the appropriate privilege level. See [Coprocessor Access Control Register on page 2-7](#).
- If Non-secure access to the Advanced SIMD features or VFP features is required, the access flags for CP10 and CP11 in the NSACR must be set to 1. See [Non-secure Access Control Register on page 2-8](#).

In addition, software must set the FPEXC.EN bit to 1 to enable most Advanced SIMD and VFP operations. See [Floating-Point Exception Register on page 2-14](#).

When Advanced SIMD and VFP operation is disabled because FPEXC.EN is 0, all Advanced SIMD and VFP instructions are treated as undefined instructions except for execution of the following in privileged modes:

- a VMSR to the FPEXC or FPSID register
- a VMRS from the FPEXC, FPSID, MVFR0 or MVFR1 registers.

[Example 2-1 on page 2-3](#) shows how to enable the Advanced SIMD and VFP in ARM *Unified Assembly Language* (UAL). This code must be executed in privileged mode.

**Example 2-1 Enabling Advanced SIMD and VFP**

---

```
MRC p15,0,r0,c1,c0,2 ; Read CPACR into r0
ORR r0,r0,#(3<<20) ; OR in User and Privileged access for CP10
ORR r0,r0,#(3<<22) ; OR in User and Privileged access for CP11
BIC r0, r0, #(3<<30) ; Clear ASEDIS/D32DIS if set
MCR p15,0,r0,c1,c0,2 ; Store new access permissions into CPACR
ISB ; Ensure side-effect of CPACR is visible
MOV r0,#(1<<30) ; Create value with FPEXC (bit 30) set in r0
VMSR FPEXC,r0 ; Enable VFP and SIMD extensions
```

---

At this point the Cortex-A9 processor can execute Advanced SIMD and VFP instructions.

---

**Note**

---

Operation is Unpredictable if you configure the *Coprocessor Access Control Register* (CPACR) so that CP10 and CP11 do not have identical access permissions.

---

## 2.2 New Advanced SIMD and VFP features

The Cortex-A9 NEON MPE implements the following new features in the ARMv7 Advanced SIMD and VFP architectures:

- [Half-precision floating-point value conversion](#)
- [Independent Advanced SIMD and VFP disable](#)
- [Dynamically configurable VFP register bank size](#).

Full details of the new instructions and control register fields are in the *ARM Architecture Reference Manual*.

### 2.2.1 Half-precision floating-point value conversion

The half-precision floating-point value conversion adds support for both IEEE and the common graphic representation, referred to as alternative-half-precision representation, of 16-bit floating-point values. This provides a smaller memory footprint for applications requiring large numbers of lower-precision floating-point values to be stored, while avoiding the overhead of conversion in software.

Additional VFP and Advanced SIMD instructions enable conversion of both individual values and vectors of values to and from single-precision floating-point representation. These values can then be processed using the rest of the VFP and Advanced SIMD instructions.

See [Floating-Point Status and Control Register on page 2-12](#) for how to select IEEE or alternative half-precision modes.

### 2.2.2 Independent Advanced SIMD and VFP disable

The independent Advanced SIMD disables permit Cortex-A9 implementations with Cortex-A9 NEON MPE to behave as though only the VFP extension were present. This lets you enable optimal operating-system task scheduling between Cortex-A9 multi-processor clusters containing both Cortex-A9 NEON MPE and floating-point only units.

The Cortex-A9 processor provides support for preventing use of this feature through Non-secure access. See [Non-secure Access Control Register on page 2-8](#) and [Coprocessor Access Control Register on page 2-7](#).

### 2.2.3 Dynamically configurable VFP register bank size

The dynamically configurable VFP register bank size provides additional support for both VFPv3-D16 and VFPv3-D32 mixed multiprocessor clusters. Cortex-A9 NEON MPE implements thirty-two 64-bit double-precision registers. VFP-only implementations are only required to support sixteen double-precision registers. This register bank disable control enables emulation of a 16-entry double-precision register file, providing both enhanced compatibility and more flexible task scheduling.

Additional control is provided in the Non-Secure Access Control Register. See [Non-secure Access Control Register on page 2-8](#) and [Coprocessor Access Control Register on page 2-7](#).



## 2.3 IEEE754 standard compliance

The IEEE754 standard provides a number of implementation choices. The *ARM Architecture Reference Manual* describes the choices that apply to the Advanced SIMD and VFPv3 architectures.

The Cortex-A9 NEON MPE implements the ARMv7 Advanced SIMD and VFP extensions. It does not provide hardware support for the following IEEE754 operations:

- remainder
- round floating-point number to nearest integer-valued in floating-point number
- binary-to-decimal conversion
- decimal-to-binary conversion
- direct comparison of single-precision and double-precision values
- any extended-precision operations.

## 2.4 Supported formats

Table 2-1 shows the formats supported for each of the Advanced SIMD and VFPv3 instruction sets implemented by the Cortex-A9 NEON MPE. All signed integers are two's complement representations.

**Table 2-1 Supported number formats**

<b>Format</b>	<b>Advanced SIMD</b>	<b>VFPv3</b>
8-bit signed/unsigned integer	Yes	No
16-bit signed/unsigned integer	Yes	No
32-bit signed/unsigned integer	Yes	Yes <sup>a</sup>
64-bit signed/unsigned integer	Yes	No
16-bit half-precision floating-point	Yes <sup>a</sup>	Yes <sup>a</sup>
32-bit single-precision floating-point	Yes	Yes
64-bit double-precision floating-point	No	Yes
8-bit polynomials	Yes	No
16-bit polynomials	Yes	No

a. For conversion purposes only.

## 2.5 Advanced SIMD and VFP register access

Table 2-2 shows the system control coprocessor registers, accessed through CP15, that determine access to Advanced SIMD and VFP registers, where:

- CRn is the register number within CP15
- Op1 is the Opcode\_1 value for the register
- CRm is the operational register
- Op2 is the Opcode\_2 value for the register.

**Table 2-2 Coprocessor Access Control registers**

CRn	Op1	CRm	Op2	Name	Description
c1	0	c0	2	CPACR	See <i>Coprocessor Access Control Register</i>
c1	0	c1	2	NSACR	See <i>Non-secure Access Control Register on page 2-8</i>

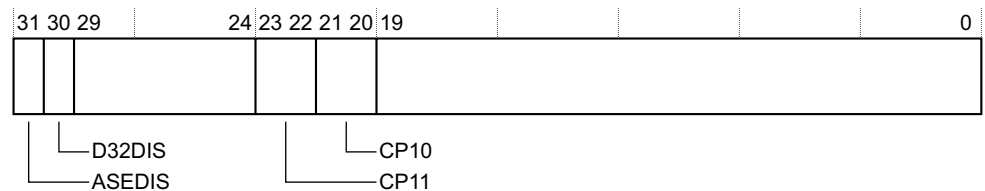
### 2.5.1 Coprocessor Access Control Register

The CPACR Register sets access rights for the coprocessors CP10 and CP11, that enable the Cortex-A9 NEON MPE functionality. This register also enables software to determine if a particular coprocessor exists in the system.

The CPACR Register is:

- a read/write register common to Secure and Non-secure states
- accessible in privileged modes only
- has a reset value of 0.

Figure 2-1 shows the CPACR Register bit assignments.



**Figure 2-1 CPACR Register bit assignments**

Table 2-3 shows the CPACR Register bit assignments.

**Table 2-3 Coprocessor Access Control Register bit assignments**

Bits	Field	Function
[31]	ASEDIS	Disable Advanced SIMD extension functionality: b1 = Disables all instruction encodings identified in the <i>ARM Architecture Reference Manual</i> as being part of the Advanced SIMD extensions but that are not VFPv3 instructions. b0 = No instructions are disabled.
[30]	D32DIS	Disable use of D16-D31 of the VFP register file: b1 = Disables all instruction encodings identified in the <i>ARM Architecture Reference Manual</i> as being VFPv3 instructions if they access any of registers D16-D31. b0 = No instructions are disabled.
[29:24]	-	See the <i>Cortex-A9 Technical Reference Manual</i> .

**Table 2-3 Coprocessor Access Control Register bit assignments (continued)**

Bits	Field	Function
[23:22]	CP11	Defines access permissions for the coprocessor. Access denied is the reset condition and is the behavior for nonexistent coprocessors. b00 = Access denied. Attempted access generates an Undefined Instruction exception. b01 = Privileged mode access only. b10 = Reserved. b11 = Privileged and User mode access.
[21:20]	CP10	Defines access permissions for the coprocessor. Access denied is the reset condition and is the behavior for nonexistent coprocessors. b00 = Access denied. Attempted access generates an Undefined Instruction exception. b01 = Privileged mode access only. b10 = Reserved. b11 = Privileged and User mode access.
[19:0]	-	See the <i>Cortex-A9 Technical Reference Manual</i> .

Access to coprocessors in the Non-secure state depends on the permissions set in the *Non-secure Access Control Register*.

Attempts to read or write the CPACR Register access bits depend on the corresponding bit for each coprocessor in *Non-secure Access Control Register*. Table 2-4 shows the results of attempted access to coprocessor access bits for each mode.

**Table 2-4 Results of access to the CRACR Register**

NSACR[11:10]	Secure privileged	Non-secure privileged	Secure or Non-secure User
b00	R/W	RAZ/WI	Access prohibited <sup>a</sup>
b01	R/W	R/W	Access prohibited <sup>a</sup>

a. User privilege access generates an Undefined Instruction exception.

To access the CPACR Register, read or write CP15 with:

MRC p15, 0, <Rd>, c1, c0, 2 ; Read Coprocessor Access Control Register  
MCR p15, 0, <Rd>, c1, c0, 2 ; Write Coprocessor Access Control Register

When the CPACR is updated, the change to the register is guaranteed to be visible only after the next *Instruction Synchronization Barrier* (ISB) instruction. When this register is updated, software must ensure that no instruction that depends on the new or old register values is issued before the ISB instruction.

Normally, software uses a read, modify, write sequence to update the CPACR, to avoid unwanted changes to the access settings for other coprocessors.

———— **Note** —————

You must enable CP10 and CP11 in the CPACR Register before accessing any Advanced SIMD or VFP system registers.

## 2.5.2 Non-secure Access Control Register

The NSACR Register defines the Non-secure access rights for the Cortex-A9 NEON MPE and other system functionality.

The NSACR Register is:

- a read/write register in Secure state
- a read-only register in Non-secure state
- only accessible in privileged modes.

Figure 2-2 shows the bit assignments of the NSACR Register relevant to the Cortex-A9 MPE. See the *Cortex-A9 Technical Reference Manual* for details of other fields in this register.

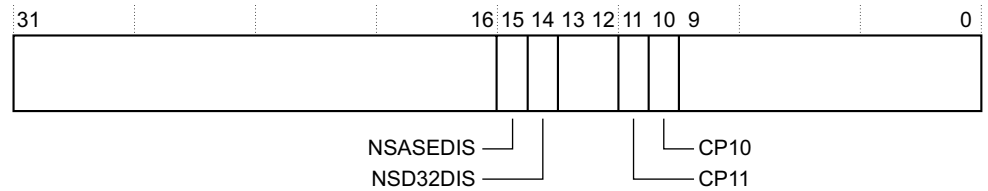


Figure 2-2 NSACR Register bit assignments

Table 2-5 shows the NSACR Register bit assignments.

Table 2-5 NSACR Register bit assignments

Bits	Field	Function
[31:16]	-	See the <i>Cortex-A9 Technical Reference Manual</i> .
[15]	NSASEDIS	Disable Non-secure Advanced SIMD extension functionality: b0 = Full access provided to CPACR.ASEDIS. b1 = The CPACR.ASEDIS bit when executing in Non-secure state has a fixed value of 1 and writes to it are ignored.
[14]	NSD32DIS	Disable Non-secure use of D16-D31 of the VFP register file: b0 = Full access provided to CPACR.D32DIS. b1 = The CPACR.D32DIS bit when executing in Non-secure state has a fixed value of 1 and writes to it are ignored.
[13:12]	-	See the <i>Cortex-A9 Technical Reference Manual</i> .
[11]	CP11	Permission to access coprocessor 11: b0 = Secure access only. This is the reset value. b1 = Secure or Non-secure access.
[10]	CP10	Permission to access coprocessor 10: b0 = Secure access only. This is the reset value. b1 = Secure or Non-secure access.
[9:0]	-	See the <i>Cortex-A9 Technical Reference Manual</i> .

To access the NSACR Register, read or write CP15 with:

```
MRC p15, 0,<Rd>, c1, c1, 2 ; Read Non-secure Access Control Register data
MCR p15, 0,<Rd>, c1, c1, 2 ; Write Non-secure Access Control Register data
```

Table 2-6 on page 2-10 shows the results of attempted access for each mode.

**Table 2-6 Results of access to the NSACR Register**

<b>Secure privileged</b>		<b>Non-secure privileged</b>		<b>User</b>	
<b>Read</b>	<b>Write</b>	<b>Read</b>	<b>Write</b>	<b>Read</b>	<b>Write</b>
Data	Data	Data	Undefined Instruction exception	Undefined Instruction exception	Undefined Instruction exception

## 2.6 Register summary

Table 2-7 shows the Cortex-A9 NEON MPE system registers. All NEON MPE system registers are 32-bit wide. Reserved register addresses are RAZ/WI.

**Table 2-7 Cortex-A9 NEON MPE system registers**

Name	Type	Reset	Description
FPSID	RO	0x41033093	See <i>Floating-Point System ID Register</i> on page 2-12
FPSCR	RW	0x00000000	See <i>Floating-Point Status and Control Register</i> on page 2-12
MVFR1	RO	0x01111111	See the <i>ARM Architecture Reference Manual</i>
MVFR0	RO	0x10110222	See the <i>ARM Architecture Reference Manual</i>
FPEXC	RW	0x00000000	See <i>Floating-Point Exception Register</i> on page 2-14

Table 2-8 shows the processor modes for accessing the Cortex-A9 NEON MPE system registers.

**Table 2-8 Accessing Cortex-A9 NEON MPE system registers**

Register	Privileged access		User access	
	FPEXC EN=0	FPEXC EN=1	FPEXC EN=0	FPEXC EN=1
FPSID	Permitted	Permitted	Not permitted	Not permitted
FPSCR	Not permitted	Permitted	Not permitted	Permitted
MVFR0, MVFR1	Permitted	Permitted	Not permitted	Not permitted
FPEXC	Permitted	Permitted	Not permitted	Not permitted

## 2.7 Register descriptions

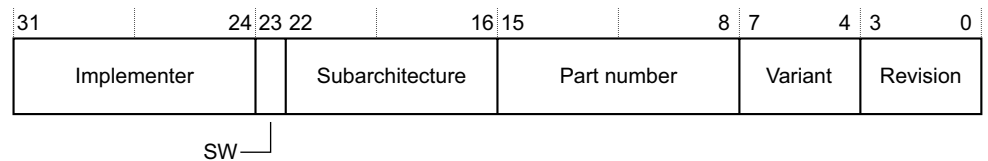
This section describes the Cortex-A9 NEON MPE system registers. [Table 2-7 on page 2-11](#) provides cross references to individual registers.

### 2.7.1 Floating-Point System ID Register

The FPSID Register characteristics are:

- Purpose** Provides information about the VFP implementation.
- Usage constraints** Only accessible in privileged modes.
- Configurations** Available in all NEON MPE configurations.
- Attributes** See the register summary in [Table 2-7 on page 2-11](#).

[Figure 2-3](#) shows the FPSID Register bit assignments.



**Figure 2-3 FPSID Register bit assignments**

[Table 2-9](#) shows the FPSID Register bit assignments.

**Table 2-9 FPSID Register bit assignments**

Bits	Name	Function
[31:24]	Implementer	Denotes ARM
[23]	SW	Hardware implementation with no software emulation
[22:16]	Subarchitecture	The null VFP sub-architecture
[15:8]	Part number	VFPv3
[7:4]	Variant	Cortex-A9
[3:0]	Revision	Revision 3

You can access the FPSID Register with the following VMRS instruction:

VMRS <Rd>, FPSID ; Read Floating-Point System ID Register

### 2.7.2 Floating-Point Status and Control Register

The FPSCR characteristics are:

- Purpose** Provides User level control of the FPU.
- Usage constraints** There are no usage constraints.
- Configurations** Available in all FPU configurations.
- Attributes** See the register summary in [Table 2-7 on page 2-11](#).

[Figure 2-4 on page 2-13](#) shows the FPSCR bit assignments.



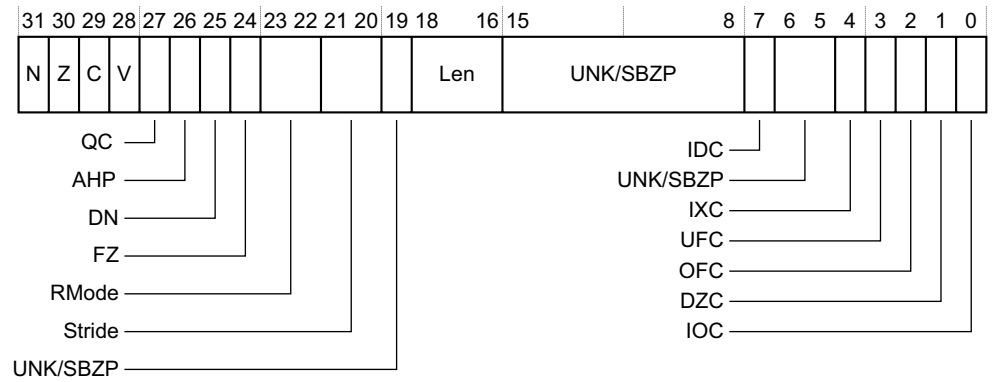


Figure 2-4 FPSCR bit assignments

Table 2-10 shows the FPSCR bit assignments.

Table 2-10 FPSCR bit assignments

Bits	Field	Function
[31]	N	Set to 1 if a comparison operation produces a less than result.
[30]	Z	Set to 1 if a comparison operation produces an equal result.
[29]	C	Set to 1 if a comparison operation produces an equal, greater than, or unordered result.
[28]	V	Set to 1 if a comparison operation produces an unordered result.
[27]	QC	Set to 1 if an Advanced SIMD integer operation has saturated since 0 was last written to this bit. <sup>a</sup>
[26]	AHP	Alternative Half-Precision control bit: b0 = IEEE half-precision format selected b1 = Alternative half-precision format selected.
[25]	DN	Default NaN mode control bit: b0 = NaN operands propagate through to the output of a floating-point operation b1 = Any operation involving one or more NaNs returns the Default NaN. Advanced SIMD arithmetic always uses the Default NaN setting, regardless of the value of the DN bit.
[24]	FZ	Flush-to-zero mode control bit: b0 = Flush-to-zero mode disabled. Behavior of the floating-point system is fully compliant with the IEEE 754 standard. b1 = Flush-to-zero mode enabled. Advanced SIMD arithmetic always uses the Flush-to-zero setting, regardless of the value of the FZ bit.
[23:22]	RMode	Rounding Mode control field: b00 = <i>round to nearest</i> (RN) mode b01 = <i>round towards plus infinity</i> (RP) mode b10 = <i>round towards minus infinity</i> (RM) mode b11 = <i>round towards zero</i> (RZ) mode. Advanced SIMD arithmetic always uses the Round to Nearest setting, regardless of the value of the RMode bits.
[21:20]	Stride	Stride control used for backwards compatibility with short vector operations. The Cortex-A9 NEON MPE ignores the value of this field. See the <i>ARM Architecture Reference Manual</i> .

**Table 2-10 FPSCR bit assignments (continued)**

Bits	Field	Function
[19]	-	UNK/SBZP.
[18:16]	Len	Vector length, used for backwards compatibility with short vector operation. If you set this field to a non-zero value, the VFP data-processing instructions generate exceptions. See the <i>ARM Architecture Reference Manual</i> .
[15:8]	-	UNK/SBZP.
[7]	IDC	Input Denormal cumulative exception flag. <sup>a</sup>
[6:5]	-	UNK/SBZP.
[4]	IXC	Inexact cumulative exception flag. <sup>a</sup>
[3]	UFC	Underflow cumulative exception flag. <sup>a</sup>
[2]	OFC	Overflow cumulative exception flag. <sup>a</sup>
[1]	DZC	Division by Zero cumulative exception flag. <sup>a</sup>
[0]	IOC	Invalid Operation cumulative exception flag. <sup>a</sup>

a. The exception flags, bit [27], bit [7], and bits [4:0] of the FPSCR are exported on the **DEFLAGS** output so they can be monitored externally to the processor, if required.

You can access the FPSCR with the following VMSR instructions:

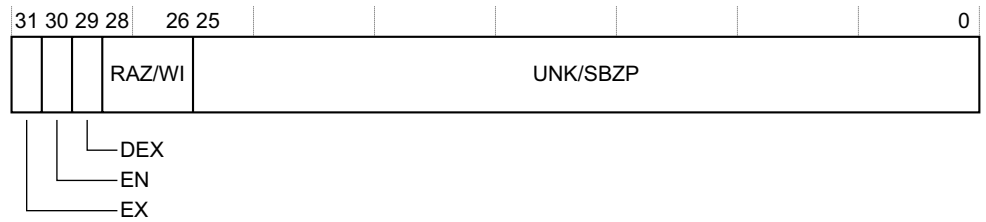
VMRS <Rd>, FPSCR ; Read Floating-Point Status and Control Register  
 VMSR FPSCR, <Rt> ; Write Floating-Point Status and Control Register

### 2.7.3 Floating-Point Exception Register

The FPEXC Register characteristics are:

- Purpose** Provides global enable control of the Advanced SIMD and VFP extensions.
- Usage constraints**
  - Only accessible in the Non-secure state if the CP10 and CP11 bits in the NSACR are set to 1, see [Non-secure Access Control Register on page 2-8](#).
  - Only accessible in privileged modes, and only if access to coprocessors CP10 and CP11 is enabled in the Coprocessor Access Control Register, see [Coprocessor Access Control Register on page 2-7](#).
- Configurations** Available in all NEON MPE configurations.
- Attributes** See the register summary in [Table 2-7 on page 2-11](#).

[Figure 2-5 on page 2-15](#) shows the FPEXC Register bit assignments.



**Figure 2-5 FPEXC Register bit assignments**

Table 2-11 shows the FPEXC Register bit assignments.

**Table 2-11 FPEXC Register bit assignments**

Bits	Name	Function
[31]	EX	Exception bit: This bit reads-as-zero and ignores-writes. The Cortex-A9 NEON MPE never requires asynchronous exception handling.
[30]	EN	Enable bit: b0 = the Advanced SIMD and VFP extensions are disabled b1 = the Advanced SIMD and VFP extensions are enabled and operate normally. The EN bit is cleared to 0 at reset.
[29]	DEX	Defined synchronous instruction exceptional flag: b0 = no exception has occurred b1 = attempt to perform a VFP vector operation has been trapped <sup>a</sup> . The DEX bit is cleared to 0 at reset.
[28:26]	-	RAZ/WI.
[25:0]	-	UNK/SBZP.

a. The Cortex-A9 NEON MPE hardware does not support the deprecated VFP short vector feature. Attempts to execute VFP data-processing instructions when the FPSCR.LEN field is non-zero result in the FPSCR.DEX bit being set and a synchronous Undefined instruction exception being taken. You can use software to emulate the short vector feature, if required.

You can access the FPEXC Register with the following VMSR instructions:

VMRS <Rd>, FPEXC ; Read Floating-Point Status and Control Register  
 VMSR FPEXC, <Rt> ; Write Floating-Point Status and Control Register

# Chapter 3

## Instruction Timing

This chapter describes the cycle timings of instructions on the Cortex-A9 NEON MPE. It contains the following sections:

- *About instruction cycle timing* on page 3-2
- *Writing optimal VFP and Advanced SIMD code* on page 3-3
- *Cortex-A9 NEON MPE instructions* on page 3-4
- *Instruction-specific scheduling* on page 3-9.

### **3.1 About instruction cycle timing**

This chapter provides information to estimate how much execution time particular code sequences require. The complexity of the Cortex-A9 processor makes it impossible to guarantee precise timing information with hand calculations. The timing of an instruction is often affected by other concurrent instructions, memory system activity, and events outside the instruction flow.

Detailed descriptions of all possible instruction interactions and events taking place in the processor are beyond the scope of this document.

## 3.2 Writing optimal VFP and Advanced SIMD code

The following guidelines can provide significant performance increases for VFP and Advanced SIMD code:

Where possible avoid:

- unnecessary accesses to the VFP control registers
- transferring values between the Cortex-A9 core registers and VFP or Advanced SIMD register file, see the *ARM Architecture Reference Manual* for definition of core registers
- register dependencies between neighboring instructions
- mixing Advanced SIMD only instructions with VFP only instructions.

Be aware that:

- with the exception of simultaneous loads and stores, the processor can execute VFP and Advanced SIMD instructions in parallel with ARM or Thumb instructions
- using Advanced SIMD value selection operations is more efficient than using the equivalent VFP compare with conditional execution.

### 3.3 Cortex-A9 NEON MPE instructions

Table 3-1 shows the instructions supported by the Cortex-A9 NEON MPE, and the instruction set that they are in, either Advanced SIMD or VFP. The data types that each instruction supports are as follows:

<b>D</b>	Double precision floating-point values
<b>F</b>	Single precision floating-point values
<b>H</b>	Half precision floating-point values
<b>I</b>	Integer values
<b>P</b>	Polynomials with single-bit coefficients
<b>X</b>	Operation is independent of data representation.

See the *ARM Architecture Reference Manual* for details of instruction encodings and functionality.

**Table 3-1 Cortex-A9 MPE instructions**

Name	Advanced SIMD	VFP	Description
VABA	I	-	Absolute Difference and Accumulate
VABAL	I	-	Absolute Difference and Accumulate Long
VABD	I, F	-	Absolute Difference
VABDL	I	-	Absolute Difference Long
VABS	I, F	F, D	Absolute
VACGE	F	-	Absolute Compare Greater Than or Equal
VACGT	F	-	Absolute Compare Greater Than
VACLE	F	-	Absolute Compare Less Than or Equal
VACLT	F	-	Absolute Compare Less Than
VADD	I, F	F, D	Add
VADDHN	I	-	Add and Narrow Returning High Half
VADDL	I	-	Add Long
VADDW	I	-	Add Wide
VAND	X	-	Bitwise AND
VBIC	I	-	Bitwise Clear
VBIF	X	-	Bitwise Insert if False
VBIT	X	-	Bitwise Insert if True
VBSL	X	-	Bitwise Select
VCEQ	I, F	-	Compare Equal
VCGE	I, F	-	Compare Greater Than or Equal
VCLE	I, F	-	Compare Less Than or Equal
VCLS	I	-	Count Leading Sign Bits
VCLT	I, F	-	Compare Less Than

Table 3-1 Cortex-A9 MPE instructions (continued)

Name	Advanced SIMD	VFP	Description
VCLZ	I	-	Count Leading Zeros
VCMP	-	F, D	Compare Setting Flags
VCNT	I	-	Count Number of Set Bits
VCVT	I, F, H	I, F, D, H	Convert Between Floating-Point and 32-bit Integer Types
VDIV	-	F, D	Divide
VDUP	X	-	Duplicate
VEOR	X	-	Bitwise Exclusive OR
VEXT	I	-	Extract Elements and Concatenate
VHADD	I	-	Halving Add
VHSUB	I	-	Halving Subtract
VLD1	X	-	Load Single-Element Structures
VLD2	X	-	Load Two-Element Structures
VLD3	X	-	Load Three-Element Structures
VLD4	X	-	Load Four-Element Structures
VLDM	X	F, D	Load Multiple Registers
VLDR	X	F, D	Load Single Register
VMAX	I, F	-	Maximum
VMIN	I, F	-	Minimum
VMLA	I, F	F, D	Multiply Accumulate
VMLS	I, F	F, D	Multiply Subtract
VMLAL	I	-	Multiply Accumulate Long
VMLSL	I	-	Multiply Subtract Long
VMOV	X	F, D	Move Register or Immediate
VMOVL	I	-	Move Long
VMOVN	I	-	Move and Narrow
VMRS	X	F, D	Move Advanced SIMD or VFP Register to ARM Compute Engine
VMSR	X	F, D	Move ARM Core Register to Advanced SIMD or VFP
VMUL	I, F, P	F, D	Multiply
VMULL	I, F, P	-	Multiply Long
VMVN	X	-	Bitwise NOT
VNEG	I, F	F, D	Negate
VNMLA	-	F, D	Negative Multiply Accumulate
VNMLS	-	F, D	Negative Multiply Subtract



Table 3-1 Cortex-A9 MPE instructions (continued)

Name	Advanced SIMD	VFP	Description
VNMUL	-	F, D	Negative Multiply
VORN	X	-	Bitwise OR NOT
VORR	X	-	Bitwise OR
VPADAL	I	-	Pairwise Add and Accumulate Long
VPADD	I, F	-	Pairwise Add
VPADDL	I	-	Pairwise Add Long
VPMAX	I, F	-	Pairwise Maximum
VPMIN	I, F	-	Pairwise Minimum
VPOP	X	F, D	Pop from Stack
VPUSH	X	F, D	Push to Stack
VQABS	I	-	Saturating Absolute
VQADD	I	-	Saturating Add
VQDMLAL	I	-	Saturating Double Multiply Accumulate Long
VQDMLSL	I	-	Saturating Double Multiply Subtract Long
VQDMULH	I	-	Saturating Doubling Multiply Returning High Half
VQDMULL	I	-	Saturating Doubling Multiply Long
VQMOVN	I	-	Saturating Move and Narrow
VQMOVUN	I	-	Saturating Move and Unsigned Narrow
VQNEG	I	-	Saturating Negate
VQRDMULH	I	-	Saturating Rounding Doubling Multiply Returning High Half
VQRSHL	I	-	Saturating Rounding Shift Left
VQRSHRN	I	-	Saturating Rounding Shift Right Narrow
VQRSHRUN	I	-	Saturating Rounding Shift Right Unsigned Narrow
VQSHL	I	-	Saturating Shift Left
VQSHLU	I	-	Saturating Shift Left Unsigned
VQSHRN	I	-	Saturating Shift Right Narrow
VQSHRUN	I	-	Saturating Shift Right Unsigned Narrow
VQSUB	I	-	Saturating Subtract
VRADDHN	I	-	Rounding Add and Narrow Returning High Half
VRECPE	I, F	-	Reciprocal Estimate
VRECPS	F	-	Reciprocal Step
VREV16	X	-	Reverse in Halfwords
VREV32	X	-	Reverse in Words

Table 3-1 Cortex-A9 MPE instructions (continued)

Name	Advanced SIMD	VFP	Description
VREV64	X	-	Reverse in Doublewords
VRHADD	I	-	Rounding Halving Add
VRSHL	I	-	Rounding Shift Left
VRSHR	I	-	Rounding Shift Right
VRSHRN	I	-	Rounding Shift Right Narrow
VRSQRTE	I, F	-	Reciprocal Square Root Estimate
VRSQRTS	F	-	Reciprocal Square Root Step
VRSRA	I	-	Rounding Shift Right and Accumulate
VRSUBHN	I	-	Rounding Subtract and Narrow Returning High Half
VSHL	I	-	Shift Left
VSHLL	I	-	Shift Left Long
VSHR	I	-	Shift Right
VSHRN	I	-	Shift Right Narrow
VSLI	X	-	Shift Left and Insert
VSQRT	-	F, D	Square Root
VSRA	I	-	Shift Right and Accumulate
VSRI	X	-	Shift Right and Insert
VST1	X	-	Store single-element structures
VST2	X	-	Store two-element structures
VST3	X	-	Store three-element structures
VST4	X	-	Store four-element structures
VSTM	X	F, D	Store Multiple Registers
VSTR	X	F, D	Store Register
VSUB	I, F	F, D	Subtract
VSUBHN	I	-	Subtract and Narrow
VSUBL	I	-	Subtract Long
VSUBW	I	-	Subtract Wide
VSWP	I	-	Swap Contents
VTBL	X	-	Table Lookup
VTBX	X	-	Table Extension
VTRN	X	-	Transpose

Table 3-1 Cortex-A9 MPE instructions (continued)

Name	Advanced SIMD	VFP	Description
VTST	I	-	Test Bits
VUZP	X	-	Unzip
VZIP	X	-	Zip

## 3.4 Instruction-specific scheduling

Complex instruction dependencies and memory system interactions make it impossible to concisely specify the exact cycle timing of all instructions in all circumstances. The following sections provide timing information that is accurate in most cases:

- [Instruction timing tables](#)
- [VFP instruction timing on page 3-10](#)
- [VFP load and store instruction timing on page 3-11](#)
- [Advanced SIMD integer arithmetic instructions on page 3-12](#)
- [Advanced SIMD integer multiply instructions on page 3-14](#)
- [Advanced SIMD integer shift instructions on page 3-15](#)
- [Advanced SIMD permute instructions on page 3-16](#)
- [Advanced SIMD floating-point instructions on page 3-17](#)
- [Advanced SIMD load-store instructions on page 3-18](#).
- [Inter-pipeline data-transfers on page 3-19](#).

For precise timing, you must use a cycle-accurate model of both your system and the processor.

### 3.4.1 Instruction timing tables

The tables in this section provide useful timing information for each category of instruction. The definition of each column is as follows:

<b>Instruction</b>	Instruction mnemonics are in the ARM UAL format. For legacy mnemonic equivalents, see the <i>ARM Architecture Reference Manual</i> .
<b>Format</b>	This is the register format of the instruction for the timing information that is provided. Where multiple formats are given in a single row, the timing information applies to all those formats. In some cases, the table provides operand type information when different operands require different computation time. For example, <a href="#">Table 3-2 on page 3-10</a> , the VFP timing table, contains .F and .D UAL modifiers for single and double-precision operations respectively. Where data-type specifiers are omitted, then you can assume the information applies to all specifiers relevant to the particular entry.
<b>Cycles</b>	This is the number of issue cycles the particular instruction consumes, and is the absolute minimum number of cycles per instruction if no operand interlocks are present.
<b>Source</b>	The Source field indicates the execution cycle where the source operands must be available if the instruction is to be permitted to issue. The comma separated list matches that of the Format field, indicating the register that each value applies to. Where two lines are provided for a single format containing quad (Q) registers, this indicates that the source registers are handled independently between top and bottom half double (D) registers. The first line provides the information for the lower half of the quad register and the second line provides the same information for the upper half of the quad register.
<b>Result</b>	The Result field indicates the execution cycle when the result of the operation is ready. At this point, the result might be ready as source operands for consumption by other instructions using forwarding paths. However, some pairs of instructions might have to wait until the value is written back to the register file.
<b>Writeback</b>	The Writeback field indicates the execution cycle that the result is committed to the register file. From this cycle, the result of the instruction is available to all other instructions as a source operand.

**Note**

An instruction might not issue if its writeback to a particular register might occur before that of an earlier instruction to the same register.

This section contains the following:

- *VFP instruction timing*
- *Advanced SIMD integer arithmetic instructions on page 3-12*
- *Advanced SIMD integer multiply instructions on page 3-14*
- *Advanced SIMD integer shift instructions on page 3-15*
- *Advanced SIMD permute instructions on page 3-16*
- *Advanced SIMD floating-point instructions on page 3-17*
- *Advanced SIMD load-store instructions on page 3-18.*

### 3.4.2 VFP instruction timing

Table 3-2 shows the VFP instruction timing.

**Table 3-2 VFP instruction timing**

Name	Format	Cycles	Source	Result	Writeback
VADD	.F Sd,Sn,Sm	1	-,1,1	4	4
VSUB	.D Dd,Dn,Dm				
VCVT	.F Sd,Sn .D Dd,Sn	1	-,1	4	4
VMUL	.F Sd,Sn,Sm	1	-,1,1	5	5
VNMUL	.D Dd,Dn,Dm	2	-,1,1	6	6
VMLA <sup>a</sup>	.F Sd,Sn,Sm	1	-,1,1	8	8
VMLS	.D Dd,Dn,Dm	2	-,1,1	9	9
VNMLS					
VNMLA					
VABS	.F Sd,Sn	1	-,1	1	2
VNEG	.D Dd,Dn				
VMOV <sup>b</sup>	Rt,Sn	1	-,1	-	-
	Rt,Rt2,Dn	1	-,1	-	-
	Dd,Rt,Rt2	1	-,1,1	1	2
	Sd,RtSd,SnDd,Dn	1	-,1	1	2
	.F Sd,#imm .D Dd,#imm	1	-,1	1	2
VMRS	Rt,FPSCR	1	-,1	-	-
VDIV	.F Sd,Sn,Sm	10	-,1,1	15	15
	.D Dd,Dn,Dm	20	-,1,1	25	25

Table 3-2 VFP instruction timing (continued)

Name	Format	Cycles	Source	Result	Writeback
VSQRT	.F Sd, Sn, Sm	13	-,1,1	17	17
	.D Dd, Dn, Dm	28	-,1,1	32	32
VCMP	.F Sn, Sm	1	1,1	1	4
	.D Dn, Dm				

- a. If a multiply-accumulate follows a multiply or another multiply-accumulate, and depends on the result of that first instruction, then if the dependency between both instructions are of the same type and size, the processor uses a special multiplier accumulator forwarding. This special forwarding means the multiply instructions can issue back-to-back because the result of the first instruction in cycle 5 is forwarded to the accumulator of the second instruction in cycle 4. If the size and type of the instructions do not match, then Dd or Qd is required in cycle 3. This applies to combinations of the multiply-accumulate instructions VMLA, VMLS, VQDMLA, and VQDMLS, and the multiply instructions VMUL and VQDMUL.
- b. The numbers in this table represent the source, result and writeback values from n MPE point of view only. See [Inter-pipeline data-transfers on page 3-19](#) for timing information about data transfers between the MPE and the ARM register file.

### 3.4.3 VFP load and store instruction timing

Table 3-3 shows the VFP load/store instruction timing.

The SP registers column gives the number of single-precision registers that are operated on. For load and store multiple operations, the number of registers in the list is equal to either 2p or 2p+1 for an even or odd number of registers respectively. Load and stores operations using addresses that are not 64-bit aligned can incur an additional cycle.

Table 3-3 VFP load and store instruction timing

Name	Format	64-bit aligned	SP registers	Cycles	Source <sup>a</sup>	Result	Writeback
VLDL	.F Sd, []	-	1	1	-	1	1
VLDL	.D Dd, []	Yes	2	1	-	1	1
		No	2	2	-	1,2	1,2
VLDM	.F Rn, {...}	Yes	2p	p	-	1, 2, ..., p	1, 2, ..., p
			2p+1	p+1	-	1, 2, ..., p+1	1, 2, ..., p+1
		No	2p	p+1	-	1, 2, ..., p+1	1, 2, ..., p+1
			2p+1	p+1	-	1, 2, ..., p+1	1, 2, ..., p+1
VLDM	.D Rn, {...}	Yes	2p	p	-	1, 2, ..., p	1, 2, ..., p
		No	2p	p+1	-	1, 2, ..., p+1	1, 2, ..., p+1
VSTR	.F Sd, []	-	1	1	-	-	-
VSTR	.D Dd, []	Yes	2	1	-	-	-
		No	2	2	-	-	-

Table 3-3 VFP load and store instruction timing (continued)

Name	Format	64-bit aligned	SP registers	Cycles	Source <sup>a</sup>	Result	Writeback
VSTM	.F Rn, {...}	Yes	2p	p	-	-	-
			2p+1	p+1	-	-	-
		No	2p	p+1	-	-	-
			2p+1	p+1	-	-	-
VSTM	.D Rn, {...}	Yes	2p	p	-	-	-
		No	2p	p+1	-	-	-

a. Store instructions can be issued before their operands are calculated.

### 3.4.4 Advanced SIMD integer arithmetic instructions

Table 3-4 shows the Advanced SIMD integer arithmetic instruction timing.

Table 3-4 Advanced SIMD integer arithmetic instruction timing

Name	Format	Cycles	Source	Result	Writeback
VADD	Dd, Dn, Dm	1	-,2,2	3	6
VAND	Qd, Qn, Qm				
VORR					
VEOR					
VBIC					
VORN					
VSUB	Dd, Dn, Dm Qd, Qn, Qm	1	-,2,1	3	6
VADDL	Qd, Dn, Dm	1	-,1,1	3	6
VSUBL					
VADDW	Qd, Qn, Dm	1	-,2,1	3	6
VSUBW					
VHADD	Dd, Dn, Dm	1	-,2,2	4	6
VRHADD	Qd, Qn, Qm				
VQADD					
VTST					
VADH	Dd, Qn, Qm	1	-,2,2	4	6
VRADH					
VSBH	Dd, Qn, Qm	1	-,2,1	4	6
VRSBH					

Table 3-4 Advanced SIMD integer arithmetic instruction timing (continued)

Name	Format	Cycles	Source	Result	Writeback
VHSUB	Dd, Dn, Dm	1	-,2,1	4	6
VQSUB	Qd, Qn, Qm				
VABD					
VCEQ					
VCGE					
VCGT					
VMAX					
VMIN					
VPMAX	Dd, Dn, Dm	1	-,2,1	4	6
VPMIN					
VNEG	Dd, Dm Qd, Qm	1	-,1	3	6
VQNEG	Dd, Dm	1	-,1	4	6
VQABS	Qd, Qm				
VABDL	Qd, Dn, Dm	1	-,2,1	4	6
VABS	Dd, Dm Qd, Qm	1	-,2	4	6
VCEQ	Dd, Dm, #imm	1	-,2,-	4	6
VCGE	Qd, Qm, #imm				
VCGT					
VCLE					
VCLT					
VPADD	Dd, Dn, Dm	1	-,1,1	3	6
VPADDL	Dd, Dn Qd, Qn	1	-,1	3	6
VMVN	Dd, Dm, Qd, Qm	1	-,2	3	6
VCLS	Dd, Dm	1	-,2	3	6
VCLZ	Qd, Qm	2	-,2	3	6
VCNT			-,3	4	7
VMOV	Dd, #imm	1	-, -	3	6
VMVN	Qd, #imm				
VORR	Dd, #imm	1	2, -	3	6
VBIC	Qd, #imm				
VBIT	Dd, Dn, Dm	1	2,2,2	3	6
VBIF	Qd, Qn, Qm	2	2,2,2	3	6
VBSL			3,3,3	4	7



**Table 3-4 Advanced SIMD integer arithmetic instruction timing (continued)**

Name	Format	Cycles	Source	Result	Writeback
VABA	Dd, Dn, Dm	1	3,2,1	6	6
	Qd, Qn, Qm	2	3,2,1 4,3,2	6	6
VABAL	Qd, Dn, Dm	1	3,2,1	6	6
VPADAL	Dd, Dm	1	3,1	6	6
	Qd, Qm				

### 3.4.5 Advanced SIMD integer multiply instructions

Table 3-5 shows the operation of the Advanced SIMD integer multiply instruction timing.

**Table 3-5 Advanced SIMD integer multiply instructions**

Name	Format	Cycles	Source	Result	Writeback
VMUL	.8 Dd, Dn, Dm	1	-,2,2	6	6
VQDMLH	.16 Dd, Dn, Dm				
VQRDMLH	.32 Dd, Dn, Dm	2	-,2,1	7	7
	.32 Qd, Qn, Qm	4	-,2,1 -,4,3	7 9	7 9
VMULL	.8 Qd, Dn, Dm	1	-,2,2	6	6
VQDMULL	.16 Qd, Dn, Dm				
	.32 Qd, Dn, Dm	2	-,2,1	7	7
VMLA	.8 Dd, Dn, Dm	1	3,2,2	6	6
VMLS	.16 Dd, Dn, Dm				
	.8 Qd, Qn, Qm	2	3,2,2	6	6
	.16 Qd, Qn, Qm		4,3,3	7	7
	.32 Dd, Dn, Dm	2	3,2,1	7	7
	.32 Qd, Qn, Qm	4	3,2,1 5,4,3	7 9	7 9
VMLAL	.8 Qd, Dn, Dm	1	3,2,2	6	6
VMLS	.16 Qd, Dn, Dm				
VQDMLAL	.32 Qd, Dn, Dm	2	3,2,1	7	7
VQDMLS					
VMUL	.16 Dd, Dn, Dm[x]	1	-,2,1	6	6
VQDMLH	.16 Qd, Qn, Dm[x]	2	-,2,1 -,3,1	6 7	6 7
VQRDMLH					
	.32 Dd, Dn, Dm[x]	2	-,2,1	7	7
	.32 Qd, Qn, Qm[x]	4	-,2,1 -,4,1	7 9	7 9

**Table 3-5 Advanced SIMD integer multiply instructions (continued)**

Name	Format	Cycles	Source	Result	Writeback
VMULL	.16 Qd,Dn,Dm[x]	1	-,2,1	6	6
VQDMULL	.32 Qd,Dn,Dm[x]	2	-,2,1	7	7
VMLA	.16 Dd,Dn,Dm[x]	1	3,2,1	6	6
VMLS	.16 Qd,Qn,Dm[x]	2	3,2,1	6	6
	.32 Dd,Dn,Dm[x]	2	3,2,1	7	7
	.32 Qd,Qn,Dm[x]	4	3,2,1 5,2,1	7 9	7 9
VMLAL	.16 Qd,Dn,Dm[x]	1	3,2,1	6	6
VMLSL	.32 Qd,Dn,Dm[x]	2	3,2,1	7	7
VQDMLAL					
VQDMLSL					

### 3.4.6 Advanced SIMD integer shift instructions

Table 3-6 shows the Advanced SIMD integer shift instruction timing.

**Table 3-6 Advanced SIMD integer shift instruction timing**

Name	Format	Cycles	Source	Result	Writeback
VSHR	Dd,Dm,#imm	1	-,1,-	3	6
VSHL	Qd,Qm,#imm				
VQSHL	Dd,Dm,#imm	1	-,1,-	4	6
VRSHR	Qd,Qm,#imm				
VSHRN	Dd,Qm,#imm	1	-,1,-	3	6
VMOVN					
VQSHRN	Dd,Qm,#imm	1	-,1,-	4	6
VQMOVN					
VQSHRN					
VQRSHR					
VSHL	Qd,Dm,#imm	1	-,1,-	3	6
VMOVL	Qd,Dm	1	-,1	3	6
VSLI	Dd,Dm,#imm	1	1,1,-	3	6
VSRI	Qd,Qm,#imm	2	1,1,- 2,2,-	3 4	6 7
VSHL	Dd,Dm,Dn	1	-,1,1	3	6
	Qd,Qm,Qn	2	-,1,1 -,2,2	3 4	6 7

**Table 3-6 Advanced SIMD integer shift instruction timing (continued)**

Name	Format	Cycles	Source	Result	Writeback
VQSHL	Dd, Dm, Dn	1	-, 1, 1	4	6
VRSHL	Qd, Qm, Qn	2	-, 1, 1	5	7
VQRSHL			-, 2, 2		
VSRA	Dd, Dm, #imm	1	3, 1, -	4	6
VRSRA	Qd, Qm, #imm	1	3, 1, -	6	6

### 3.4.7 Advanced SIMD permute instructions

Table 3-7 shows the operation of the Advanced SIMD permute instruction timing.

**Table 3-7 Advanced SIMD permute instruction timing**

Name	Format	Cycles	Source	Result	Writeback
VDUP	Dd, Dm[x]	1	-, 1	2	6
VTRN	Qd, Qm[x]				
VSWP	Dd, Dm	1	1, 1	2	6
	Qd, Qm	2	1, 1	2	6
			2, 2	3	7
VZIP	Dd, Dm	1	1, 1	2	6
	Qd, Qm	3	1, 1 2, 2	3, 4	7, 8
VUZP	Dd, Dm	1	1, 1	2	6
	Qd, Qm	3	1, 2	3	7
VREV	Dd, DmQd, Qm	1	-, 1	2	6
VEXT	Dd, Dn, Dm, #imm	1	-, 1, 1, -	2	6
	Qd, Qn, Qm, #imm	2	-, 1, 2, -	3	7
VTBL	Dd, {Dn}, Dm	2	-, 2, 1	3	7
	Dd, {Dn, Dn1}, Dm	2	-, 2, 2, 1	3	7
	Dd, {Dn, Dn1, Dn2}, Dm	3	-, 2, 2, 3, 1	4	8
	Dd, {Dn, Dn1, Dn2, Dn3}, Dm	3	-, 2, 2, 3, 3, 1	4	8
VTBX	Dd, {Dn}, Dm	2	1, 2, 1	3	7
	Dd, {Dn, Dn1}, Dm	2	1, 2, 2, 1	3	7
	Dd, {Dn, Dn1, Dn2}, Dm	3	1, 2, 2, 3, 1	4	8
	Dd, {Dn, Dn1, Dn2, Dn3}, Dm	3	1, 2, 2, 3, 3, 1	4	8

### 3.4.8 Advanced SIMD floating-point instructions

Table 3-8 shows the Advanced SIMD floating-point instructions.

**Table 3-8 Advanced SIMD floating-point instructions**

Name	Format	Cycles	Source	Result	Writeback
VADD	Dd, Dn, Dm	1	-,2,2	5	6
VSUB	Qd, Qn, Qm	2	-,2,2	5	6
VABD			-,3,3	6	7
VMUL					
VCEQ					
VCGE					
VCGT					
VACGE					
VACGT					
VMAX					
VMIN					
VABS	Dd, Dm	1	-,2	5	6
VNEG	Qd, Qm	2	-,2	5	6
VRECPE			-,3	6	7
VRSQRTE					
VCVT					
VCEQ	Dd, Dm, #imm	1	-,2	5	6
VCGE	Qd, Qm, #imm	2	-,2	5	6
VCGT			-,3	6	7
VCLE					
VCLT					
VPADD	Dd, Dn, Dm	1	-,1,1	5	6
VPMAX					
VPMIN					
VMUL	Dd, Dn, Dm[x]	1	-,2,1	5	6
	Qd, Qn, Dm[x]	2	-,2,1	5	6
			-,3,1	6	7
VMLA	Dd, Dn, Dm	1	3,2,2	9	10
VMLS	Qd, Qn, Qm	2	3,2,2	9	10
			4,3,3	10	11
	Dd, Dn, Dm[x]	1	3,2,1	9	10
	Qd, Qn, Dm[x]	2	3,2,1	9	10
			4,3,1	10	11
VRECPS	Dd, Dn, Dm	1	-,2,2	9	10
VRSQRTS	Qd, Qm, Qn	2	-,2,2	9	10
			-,3,3	10	11

### 3.4.9 Advanced SIMD load-store instructions

Table 3-9 shows the Advanced SIMD load-store instruction timing.

The values in Table 3-9 correspond to the number of issue cycles required within the MPE execution unit. The number of cycles required by the Cortex-A9 integer processor is equal to the number of 64-bit aligned doublewords that the NEON load or store data overlaps.

**Table 3-9 Advanced SIMD load-store instructions**

Name	Format	Cycles	Source	Result	Writeback
VLD1	{Dd}, []	2	-	2	7
	{Dd}, [@]	1	-	1	6
	{Dd, Dd1}, []	2	-, -	2, 2	7, 7
	{Dd, Dd1}, [@]	1	-, -	1, 1	6, 6
	{Dd, Dd1, Dd2}, []	3	-, -, -	2, 2, 3	7, 7, 8
	{Dd, Dd1, Dd2}, [@]	2	-, -, -	1, 1, 2	6, 6, 7
	{Dd, Dd1, Dd2, Dd3}, []	3	-, -, -, -	2, 2, 3, 3	7, 7, 8, 8
	{Dd, Dd1, Dd2, Dd3}, [@]	2	-, -, -, -	1, 1, 2, 2	6, 6, 7, 7
	{Dd[x]}, []	3	1	4	8
	{Dd[x]}, [@]	2	1	3	7
	{Dd[]}, []	2	-	3	7
	{Dd[]}, [@]	1	-	2	6
	{Dd[], Dd1[]}, []	2	-, -	3, 3	7, 7
	{Dd[], Dd1[]}, [@]	1	-, -	2, 2	6, 6
VLD2	{Dd, Dd1}, []	2	-, -	3, 3	7, 7
	{Dd, Dd1}, [@]	1	-, -	2, 2	6, 6
	{Dd, Dd1, Dd2, Dd3}, []	3	-, -, -, -	3, 4, 3, 4	7, 8, 7, 8
	{Dd, Dd1, Dd2, Dd3}, [@]	2	-, -, -, -	2, 3, 2, 3	6, 7, 6, 7
	{Dd[x], Dd1[x]}, []	3	1, 1	4, 4	8, 8
	{Dd[x], Dd1[x]}, [@]	2	1, 1	3, 3	7, 7
	{Dd[], Dd1[]}, []	2	-, -	3, 3	7, 7
{Dd[], Dd1[]}, [@]	1	-, -	2, 2	6, 6	
VLD3	{Dd, Dd1, Dd2}, []	4	-, -, -	4, 4, 5	8, 8, 9
	{Dd, Dd1, Dd2}, [@]	3	-, -, -	3, 3, 4	7, 7, 8
	{Dd[x], ..., Dd2[x]}, []	5	1, 1, 2	5, 5, 6	9, 9, 10
	{Dd[], Dd1[], Dd2[]}, []	3	-, -, -	3, 3, 4	7, 7, 8

Table 3-9 Advanced SIMD load-store instructions (continued)

Name	Format	Cycles	Source	Result	Writeback
VLD4	{Dd,Dd1,Dd2,Dd3}, []	4	-, -, -	4,4,5,5	8,8,9,9
	{Dd,Dd1,Dd2,Dd3}, [@]	3	-, -, -	3,3,4,4	7,7,8,8
	{Dd[x], ..., Dd3[x]}, []	5	1,1,2,2	5,5,6,6	9,9,10,10
	{Dd[x], ..., Dd3[x]}, [@]	4	1,1,2,2	4,4,5,5	8,8,9,9
	{Dd[], ..., Dd3[]}, []	3	-, -, -	3,3,4,4	7,7,8,8
	{Dd[], ..., Dd3[]}, [@]	2	-, -, -	2,2,3,3	6,6,7,7
VST1	{Dd}, []	2	1	-	-
	{Dd}, [@]	1	1	-	-
	{Dd[x]}, []	2	1	-	-
	{Dd[x]}, [@]	1	1	-	-
VST2	{Dd,Dd1}, []	2	1,1	-	-
	{Dd,Dd1}, [@]	1	1,1	-	-
	{Dd[x], Dd1[x]}, []	2	1,1	-	-
	{Dd[x], Dd1[x]}, [@]	1	1,1	-	-
VST3	{Dd,Dd1,Dd2}, []	3	1,1,2	-	-
	{Dd,Dd1,Dd2}, [@]	2	1,1,2	-	-
	{Dd[x], ..., Dd2[x]}, []	3	1,1,2	-	-
VST4	{Dd,Dd1,Dd2,Dd3}, []	3	1,1,2,2	-	-
	{Dd,Dd1,Dd2,Dd3}, [@]	2	1,1,2,2	-	-
	{Dd[x], ..., Dd3[x]}, []	3	1,1,2,2	-	-
	{Dd[x], ..., Dd3[x]}, [@]	2	1,1,2,2	-	-

### 3.4.10 Inter-pipeline data-transfers

A Cortex-A9 processor, implemented with the MPE, contains distinct data-processing units:

- the integer core
- a unit, within the MPE, for handling Advanced-SIMD instructions
- a unit, within the MPE, for handling VFP instructions

In addition to the cycles listed in the previous tables for data movement within a unit, additional latencies apply for moving data values between units. [Table 3-10](#) shows the additional latency incurred for moving values between the three units, either using explicit move instructions, or in the case of Advanced-SIMD to or from VFP fields, where a value generated by one unit is consumed by another:

**Table 3-10 Inter-unit latencies**

From	To		
	Integer Core	Advanced-SIMD	VFP
Integer Core	-	0	0
Advanced-SIMD	11	-	-
VFP	3	-	-

The VFP and Advanced-SIMD units can not execute concurrently. All instructions targeting either the Advanced-SIMD or VFP units complete before later instructions are issued on the other unit.

# Appendix A

## Revisions

This appendix describes the technical changes between released issues of this book.

**Table A-1 Differences between issue A and issue B**

<b>Change</b>	<b>Location</b>
Removed text stating that implementation of Security Extensions is optional	Throughout book
Created separate entry for the VSWP instruction	<a href="#">Table 3-7 on page 3-16</a>
Updated values for the VMLA, VMLS, VRECPs, and VRSQRTS instructions	<a href="#">Table 3-8 on page 3-17</a>

**Table A-2 Differences between issue B and issue C**

<b>Change</b>	<b>Location</b>
Modified the example code for enabling the Advanced SIMD and VFP extensions in ARM Unified Assembly Language	<a href="#">Example 2-1 on page 2-3</a>
Updated FPSCR bit assignments table	<a href="#">Table 2-10 on page 2-13</a>

**Table A-3 Differences between issue C and issue D**

<b>Change</b>	<b>Location</b>
Value for version updated to 2	<a href="#">Table 2-7 on page 2-11</a>
FPSCR SBZ/WI bits retitled to UNK/SBZP	<a href="#">Table 2-10 on page 2-13</a> and <a href="#">Figure 2-4 on page 2-13</a>
SBZ/WI bits retitled to UNK/SBZ	<a href="#">Table 2-11 on page 2-15</a> and <a href="#">Figure 2-5 on page 2-15</a>



**Table A-3 Differences between issue C and issue D (continued)**

<b>Change</b>	<b>Location</b>
Added Footnote about special behavior of two VMLA instructions	<a href="#">Table 3-2 on page 3-10</a>
Footnote reworded	<a href="#">Table 3-3 on page 3-11</a>
Added paragraph about timings	<a href="#">Table 3-9 on page 3-18</a>
Table formatting fixes	<a href="#">Table 3-3 on page 3-11</a> <a href="#">Table 3-4 on page 3-12</a> <a href="#">Table 3-5 on page 3-14</a> <a href="#">Table 3-6 on page 3-15</a> <a href="#">Table 3-7 on page 3-16</a> <a href="#">Table 3-8 on page 3-17</a> <a href="#">Table 3-9 on page 3-18</a>

**Table A-4 Differences between issue D and Issue E**

<b>Change</b>	<b>Location</b>
No technical change	-

**Table A-5 Differences between issue E and Issue F**

<b>Change</b>	<b>Location</b>
ISB added to code example	<a href="#">Example 2-1 on page 2-3</a>
Harmonized FPEXC bit descriptions with the FPU TRM descriptions	<a href="#">Table 2-11 on page 2-15</a>

**Table A-6 Differences between issue F and issue G**

<b>Change</b>	<b>Location</b>	<b>Affects</b>
No technical change	-	-